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Original Article

The effect of beverage temperature on the surface roughness, microhardness, and color stability of the monoshade composite resin: An *in vitro* study

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ABSTRACT

Objective: This study assessed the impact of beverage temperature on the surface roughness, microhardness, and color stability of monoshade composite resin.
Materials and Methods: A batch of 70 monoshade composite resin specimens manufactured by Charisma Diamond ONE (Kulzer, Hanau, Germany) was prepared. Initial readings for surface roughness, microhardness, and color were recorded. The specimens were then divided into seven groupings of ten each: Distilled water (control group), Nescafe coffee at 70 °C and 5 °C, Arabic coffee at 70 °C and 37 °C, and cola at 7 °C and 24 °C. These samples underwent 30-min daily immersion in their respective beverages for a duration of 30 days. Final measurements were then taken. A non-contact profilometer was used for measuring surface roughness, a Vickers microhardness machine from Contour GT-I (Bruker Nano GmbH, Berlin, Germany) for microhardness, and a Color-Eye 7000A Spectrophotometer (X-Rite, GretagMacbeth, Michigan USA) for color stability. Statistical analyses, including repeated measure ANOVA for microhardness, roughness, and color, were executed using SPSS version 23.
Results: All beverages led to changes in composite color and properties. Notably, coffee at 70 °C resulted in significant discoloration of the composite resin surface ($p < 0.0001$). The beverage that most affected the surface hardness and roughness of the monoshade composite resin was cola at 7 °C ($p = 0.008$)
Conclusion: The inherent chemicals in beverages, coupled with their temperatures, can influence the composite properties of resin, specifically surface discoloration, hardness, and roughness. Clinicians may, therefore, consider instructing patients about the potential negative effects of these beverages.

1. Introduction

Composite resin, introduced 50 years ago, has become one of the most commonly used dental fillings (Zhou et al., 2019). Gradual refinements in its aesthetic appeal, properties, application technique, and formulation have been made over time (Zhou et al., 2019). It has also addressed the limitations of alternatives like amalgam by preserving tooth structure and forming a chemical bond to enamel and dentin (Ilie and Hickel, 2011). The ability to closely mimic natural dentition is crucial for aesthetic fillings (Choi et al.,2005). Color discrepancies in restorations are the primary reason for replacements, emphasizing the importance of color accuracy (Samra et al.,2008). Beyond color, fine-tuned surface texture and gloss contribute significantly to the overall aesthetic result, necessitating meticulous attention to detail (Zinelis et al., 2005).

Temperature fluctuations in patient's food and beverages can affect restorative materials in the oral cavity, potentially leading to marginal gap formation and recurrent caries and pulpal disease (Sidhu et al., 2004). Ensuring that restorations maintain smooth surfaces is crucial for aesthetic purposes. Surface texture, including smoothness or absence of

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roughness, significantly impacts restoration performance and durability, as rough surfaces can cause plaque accumulation, gingivitis, and recurrent caries (Hilal and Ranjan, 2020).

Limited research explored beverage temperature's impact on composite resin characteristics, especially in Saudi Arabia, the second-largest tea consumer in the Arab region (Ashraf, 2011; Benajiba and Eldib, 2018), and the 66th position among 150 countries in terms of per capita coffee consumption (Coffee consumption per capita in Saudi Arabia, 2022; Al-Othman et al., 2012; Al-Aali and Ayub, 2015).

According to the manufacturer, the molecular structure of Charisma Diamond One composite exhibits exceptional flexural strength due to its combination of high strength and minimal shrinkage. This, in turn, minimizes the risk of restoration fractures, which, along with recurrent caries, are the primary causes of restoration failures (Kulzer, 2017). However, there have been limited studies examining the properties of Charisma Diamond ONE composite. This study examined the influence of beverage temperature on surface roughness, hardness, and color stability of Charisma Diamond ONE composite resin to predict its long-term aesthetic and functional performance when utilizing a laboratory-processed composite resin.

The rapid development of new restorative resins can be attributed to the increasing demand for aesthetics in dentistry. Color match and stability are two pivotal factors that determine the success of an aesthetic restoration (Gupta et al.,2005). This study serves as a model for future real-life patient experimental studies, enabling us to evaluate the long-term effects of the composite resin. Additionally, it aims to raise awareness among patients regarding the potential detrimental effects of excessive consumption of beverages at varying temperatures in order to achieve a prolonged and successful treatment outcome.

The null hypothesis posits that the temperature of beverages will not have an impact on composite properties.

2. Materials and methods

This 6-month *in vitro* study was conducted from 26 January to 26 July 2022. We received ethical approval from the college's Scientific Research Unit, as the Institutional Review Board's approval was not necessary for this type of research.

2.1. Preparation of composite resin

A mold was devised for the single-shaded Charisma Diamond ONE samples (Kulzer, Hanau, Germany). The mold, 10 mm in diameter and 2 mm thick, was slightly overfilled with composite. Excess was scraped off using Mylar strips while pressure was applied using a glass slab. Composite samples were then flash-cured using a Mini LED device (ACETEON, Codex, France). This process was done in three 20-s stages on both mold sides and were inspected upon removal of the glass slab for internal porosities or voids under natural light. Those with voids were discarded. The samples were stored in distilled water at 37 °C for 24 h before being finished and polished – emulating post-polymerization oral conditions (Malhotra et al., 2011). The samples were polished using 3M™ Sof-Lex™ aluminum oxide disks, starting with a medium (2382 M) grade and concluding with superfine (2382SF), ensuring constant water coolant. Polishing was limited to 10 s for each stage to prevent micro-crack formation (Marghalani, 2010).

2.2. Grouping of specimens and surface treatment with beverages

The mean color change on composite resin under the effect of cola versus coffee at 37 °C was respectively 2.65 ± 0.74 and 3.86 ± 1.25, with a standard deviation of 0.99 (Akalın et al., 2019). With a 5 % margin of error, 90 % power, and 95 % confidence level, at least ten specimens per subgroup were necessary. As such, 70 monoshade composite samples were used and finalized with Sof-Lex aluminum oxide discs. Specimens from Omnichroma (Yokoyama Dental, Japan) were prepared, and initial measurements of roughness, microhardness, and color were taken.

These specimens were then randomly divided into seven groups, with each group varying by the immersion solution and temperature: Nescafe coffee at 70 °C and 5 °C, Arabic coffee at 70 °C and 24 °C, cola at 7 °C, and distilled water (control group). Each group contained ten specimens. Every specimen was immersed in its respective solution twice daily for 15 min (morning and afternoon) over a 30-day period. The temperature, set at a specific level at the start of each immersion, was allowed to gradually acclimate to room temperature during the immersion phase as a simulation of typical conditions.

After the final measurements were taken, the specimens were washed with distilled water, left to dry for a day, and then assessed for any surface changes.

2.3. Surface roughness analysis

All specimens were tested using a Contour GT-I surface roughness tester (Bruker Nano GmbH, Berlin, Germany). This non-contact profilometer features a tip/tilt in the head and an integrated air isolation table and uses white light interferometry for comprehensive surface characterization. Each specimen was positioned horizontally on the stage for measurement at the polished surface's center, with three separate measurements taken in different directions. Utilization of the system's automated and programmable functions, as well as its vibration resistance, significantly reduced tracking errors. Regular performance checks were carried out using a calibration block for device accuracy.

2.4. Surface microhardness analysis

The Vickers surface hardness of each specimen was assessed using a MicroMet 6040 Microhardness Testing Machine (Buehler, Illinois, USA). Indentations were created on the specimens' polished surfaces with a Vickers diamond indenter, applying a 100-g load for 10 s. Three average indents were used in the analysis. We collected hardness data before and after beverage exposure.

2.5. Color stability analysis

The color of the specimens was measured by The Color-Eye 7000A Spectrophotometer (X-Rite, Incorporated and GretagMacbeth, Michigan USA), with the CIELAB scale L*, a*, and b*, and $\Delta E = [(\Delta L)\ 2+ (\Delta a)\ 2+ (\Delta b)\ 2]^{1/2}$, was assessed, where ΔL, Δa, and Δb are the color dimensions difference between the color at baseline and LX, X-time interval (X = before immersion and after immersion). L* represents the lightness; L = 0 = black, L = 100 = diffused white. a* negative value indicates green, whereas a positive value indicates magenta. b* negative value indicates blue, whereas a positive value indicates yellow.

Three color measurements were collected for each sample both before immersion (baseline) and after 1 month of beverage exposure.

2.6. Statistical analysis

Descriptive statistics were presented as mean and standard deviations while ANOVA evaluated changes in microhardness, roughness, and color over time and between groups. This analysis was executed using SPSS version 23. The Bonferroni test and *t*-test for pairwise comparison were employed to assess significant changes within the groups. To examine how different beverages affected the test resin composite's color shade, surface roughness, and microhardness, a two-way ANOVA test was conducted. Statistical significance was set at ≤ 0.05.

3. Results

The changes in shade, surface roughness, and microhardness were assessed in 70 composite resin specimens.

3.1. Changes in shade

Table 1 presents the composite resin's average shade changes for each beverage. No significant differences (P = 0.066) were observed on composite shades at baseline. However, the shades significantly differed when the resin was immersed in different beverages (P = 0.000). Specifically, immersing the resin in coffee at 70 °C significantly altered its shade compared to all other beverages (Fig. 1).

3.2. Changes in microhardness

The study revealed significant variations in the microhardness values of the composite resin tested, both at baseline and after immersion in different beverages (P = 0.005 for all). When immersed in coffee at 5 °C, followed by immersion in cola at 7 °C, notable differences were observed (P = 0.029). Similarly, distinct changes occurred when the composite was first immersed in cola at 24 °C, then at 7 °C (P = 0.008). Further, immersion in cola at 7 °C, followed by immersion in coffee at 5 °C (P = 0.029), and subsequently in cola at 24 °C (P = 0.008), resulted in significant differences as well (Table 2).

3.3. Changes in surface roughness

The mean surface roughness values of the composite resin did not show any significant differences, both at baseline (P = 0.241) and after immersion (P = 0.059) within various beverages. Yet, significant differences appeared after immersion in 70 °C coffee (P = 0.005), as well as in 5 °C coffee (P = 0.049). Additionally, immersion in 70 °C and 37 °C Arabic coffee resulted in notable differences in surface roughness (P = 0.044) and (P = 0.006), respectively(Fig. 2). The same was evident following immersion in 7 °C cola (P = 0.002) (Table 3).

The data collected show the significant impact different beverages have on the color alterations of the assessed resin composites. This is illustrated by p-values of less than 0.001 and 0.015 before and after immersion, respectively. Significant differences in microhardness were also observed before immersion with a p-value of less than 0.001 (Table 4).

4. Discussion

The current study assessed the impact of beverage temperature on composite properties and revealed that coffee at 70 °C caused significant discoloration on composite resin surfaces, while Cola at 7 °C reduced surface hardness and increased roughness of mono composite resin. Additionally, Arabic coffee was found to affect the composite properties, including color change, microhardness, and surface roughness. Thus, the hypothesis of the study was confirmed.

Beltrami et al. (2022) investigated the potential impact of temperature and acidic fluids on restorative composite resin, aiming to predict the durability of filling materials and identify effective preventive practices. However, concrete evidence regarding the exact effects and intensity of the composite resin remains unfounded. The roughness values for both cola groups exceeded the baseline values. Notably, the 70 °C coffee group showed marked color changes on ΔE measurements (Tuncer et al., 2013), a finding consistent with Karaman et al. (2015), who reported significant discoloration of all tested composites after coffee submersion. Compared to other beverages, coffee also impacted surface roughness and microhardness across all composites. Filtek Supreme XT, notably, experienced the greatest change in microhardness after being immersed in coffee (Karaman et al., 2015).

Table 1
Means (+SD) comparison for shade changes of tested composite resin (N = 70).

	Before immersion		After immersion	P-value
Beverage	N	Mean (±SD)		
Control	10	149.7(±4.7)	141.1(±14.3)	0.090
Coffee 70C	10	149.3(±7.1)	122.4(±5.1)	**0.0001***
Coffee 5C	10	151.0(±9.4)	147.2(±12.5)	0.111
Arabic coffee 70C	10	150.7(±11)	139.9(±6.9)	**0.010***
Arabic coffee 37C	10	143.3(±8.3)	138.8(±8.2)	0.122
Cola 24C	10	142.0(±6.7)	140.3(±8.6)	0.307
Cola 7C	10	145.1(±8.2)	136.7(±7.8)	**0.007***
Total	70	147.3(±8.5)	138.1(±11.6)	**0.000***

*Shows statistically significant difference at 5% level of significance.

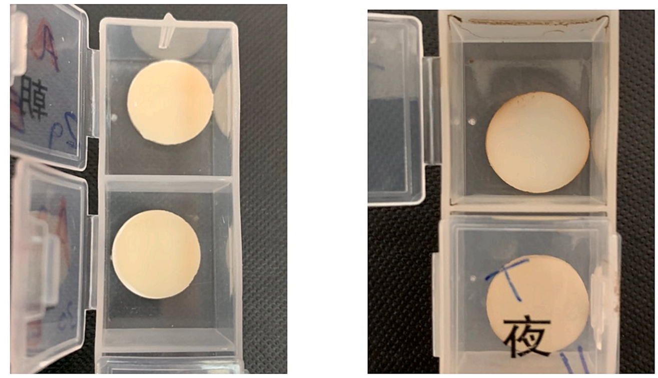

Fig. 1. Images samples at baseline ans after immersion in Coffee 70C for 15 min 2 times a day for 30 days.

Table 2
Means (+SD) comparison for microhardness changes of tested composite resin (N = 70).

Beverage	N	Before immersion	After immersion	P-value
		Mean (±SD)		
Control	10	123.1(±16.9)	154.0(±12.4)	**0.001***
Coffee 70C	10	160(±17.5)	161.1(±16.7)	0.869
Coffee 5C	10	157.6(±20)	173.2(±14.78)	**0.016***
Arabic coffee 70C	10	151(±22.9)	167.65(±36.2)	0.162
Arabic coffee 37C	10	138.7(±23.6)	151.2(±21.6)	**0.032***
Cola 24C	10	159.5(±19.5)	177.4(±21.8)	**0.021***
Cola 7C	10	163.1(±25.8)	141.3(±21.4)	**0.006***
Total	70	150.4(±24.3)	160.8(±24.1)	**0.000***

*Shows statistically significant difference at 5% level of significance.

Hot beverages like tea, coffee, and Arabic coffee (Qahwa) significantly affect composite resin more than average or cold temperatures. An Egyptian dental clinician demonstrated that water and natural milk do not seem harmful to restorative materials, in contrast, drinks like mango juice, orange, and Mirinda citric drinks showed potential damage (Hamouda, 2011). A separate study investigating the impact of fluids such as cola, orange, acid, kefir, and saliva arrived at similar conclusions (Guler and Unal, 2018). Asiatic drinks like cola and gastric acid increase surface roughness and discoloration in dental restorative materials, leading to aesthetic and functional issues in dental filling restorations.

The composite resin exhibited more discoloration when exposed to hot coffee, possibly due to its lower pH at 70 °C, which may affect its surface quality and sensitivity to stains. In line with these findings, our study showed that hotter coffee significantly impacted the resin surface, leading to less surface hardness and more staining.

Coffee staining occurs due to polar colorants absorbing onto a material's surface, causing discoloration in composite samples. Despite lower pH in cola, which could potentially harm resin composite materials, it doesn't cause as much staining due to the absence of yellow pigments. Our findings align with previous research conducted by Bagheri et al. (2005), Patel et al., 2004, and Barutcigil and Yıldız, 2012, further underscoring the fact that coffee tends to cause more discoloration compared to cola.

The results of the current study's spectrophotometer show significant color changes in samples submerged in coffee and, to a lesser extent,

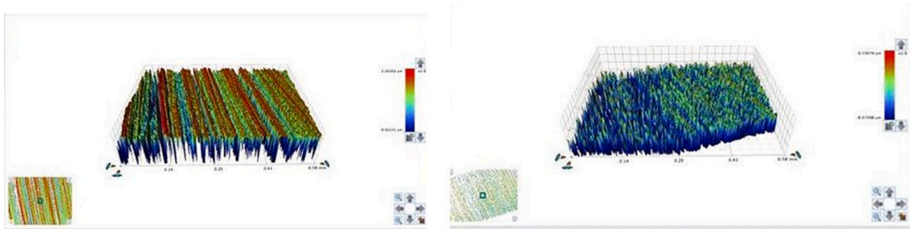

Fig. 2. 3D-images of the sample before and after surface roughness testing using the non contact profilometer (Bruker Nano GmbH).

Table 3
Means (+SD) comparison for surface roughness of tested composite resin (N = 70).

Beverages	N	Before immersion Mean (±SD)	After immersion	P-value
Control	10	426.9(±113.7)	567.8(±74.4)	**0.004***
Coffee 70C	10	469.3(±55.6)	538.3(±56.4)	**0.005***
Coffee 5C	10	475.5(±67.0)	562.7(±82.6)	**0.049***
Arabic coffee 70C	10	497.6(±95.3)	585.2 + 68.4)	**0.044***
Arabic coffee 37C	10	410.5(±63.3)	559.1(±83.4)	**0.006***
Cola 24C	10	494.3(±119.6)	531.2(±151.8)	0.189
Cola 7C	10	436.8(±93.4)	663.0(±84.6)	**0.002***
Total	70	459.7(±91.8)	571.4(±95.3)	0.059

*Shows statistically significant difference at 5% level of significance.

Table 4
Two-way ANOVA test for comparison of color shade, surface roughness and microhardness measures under the effect of beverages.

Tests of Between-Subjects Effects					
Dependent Variable: Solution					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	94.799[a]	6	15.800	5.375	**<0.001***
Intercept	6.253	1	6.253	2.127	0.150
Color shade before immersion	44.561	1	44.561	15.158	**<0.001***
Color shade after immersion	18.578	1	18.578	6.320	**0.015**
Surface roughness before immersion	2.407	1	2.407	0.819	0.369
Surface roughness after immersion	8.085	1	8.085	2.750	0.102
Microhardness before immersion	36.438	1	36.438	12.395	**<0.001***
Microhardness after immersion	6.106	1	6.106	2.077	0.154
Error	185.201	63	2.940		
Total	910.000	70			
Corrected Total	280.000	69			

a. R Squared = 0.339 (Adjusted R Squared = 0.276).
*Shows statistically significant difference at 5% level of significance.

cola. Distilled water resulted in the smallest color differences. The changes in color observed with coffee exceeded the clinical limits of acceptability. This finding is consistent with previous research, suggesting that coffee tends to cause more discoloration in resin-based composites. For instance, studies by Al-Dulaijan et al. (2023), Gupta et al., 2019, Mundim et al. (2010), and Macedo et al. (2018) support this. This study also supports the reports by Guler et al. and Ertas et al., which found that coffee and tea caused more discoloration in resin-based composites than cola.

The quality of a composite surface, which relates to any discoloration, is influenced by both its material composition and the processes of finishing and polishing. In this study, with constant water cooling implemented, we used Sof-Lex aluminum oxide polishing disks to polish the specimens. This process started with coarse polishing and finished with extra fine, as outlined in Aydın et al., (2021).

Research on beverage temperature's impact on composite resin surface characteristics is limited, necessitating further studies to fully understand its influence on these resins. The addition of nanoparticles was found to enhance the flexural strength, wear resistance, and hardness of composites in lab tests (Azmy et al., 2022). Therefore, it is recommended future studies investigate these effects clinically on patients.

While the current study, with its limitations, only examined *in vitro* effects, the results suggest that a notable color change in the oral environment could occur over a significantly longer period if it is not repeatedly exposed to hot coffee, saliva, or other fluids known to dissolve filling material or if restorations are not compromised by brushing. If retention times are extended, a larger statistical difference may result; thus, this *in vitro* research should be supported by in vivo studies. The surface characteristics of composite resin material, including microhardness and roughness, can be influenced by beverages' chemical composition, acid type, and individual components, potentially guiding clinicians.

4.1. Limitations of the study

The current study faced two noteworthy limitations. Firstly, it only included material-based groups, neglecting the need for both positive and negative control groups, such as human-extracted teeth. Secondly, the experiment used mixed-type specimens, including incisors, canines, and molars, instead of focusing on a specific type, for example, aesthetic region or molars. This lack of specificity may influence the accuracy of the machine's composite property measurements, as it seemed to produce misleading results on occasion. Furthermore, taking an average of three readings does not necessarily represent the most accurate value.

5. Conclusion

Drinking coffee at around 70 °C can significantly discolor composite resin. Consuming cola at approximately 7 °C was noticed to notably impact the surface hardness and roughness of mono composite resin. Arabic coffee can alter the properties of composite materials, resulting in color variations, diminished microhardness, and changes in surface texture. Dental practitioners might advise patients to limit the excessive intake of these beverages, use straws when drinking, and maintain excellent oral hygiene to mitigate these effects.

6. Authors' contributions

RS conceptualization and design of the study, acquisition of data, and supervision of the experiment. **YM, FE**, and **SZ** acquisition of data and writing the first draft of the manuscript. **IS & BG** data analysis and interpretation, and critical revision of the manuscript. All authors revised and approved the final version of the manuscript.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sdentj.2024.03.002.

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